Claim 63 - A method for loss on drying, the steps including:

establishing a benchmark correlative to a level of microwave energy sensed by a sensor;

employing the sensor to monitor a level of microwave energy within a chamber wherein a sample which tracks the benchmark is being radiated;

comparing the monitored energy level with the benchmark level for controlling a drying process of the sample by discerning when the benchmark is attained.

Claim 64 - A method for loss on drying, the steps including:

establishing a characteristic radiation curve of a sample type correlative of its radiation absorbability;

radiating a sample contained within a chamber;

sensing radiation changes in the chamber which correlates to the sample's relative dryness;

comparing subsequently sensed levels of radiation within the chamber with the characteristic radiation curve for determining an endpoint condition when the sample is dry.

REMARKS

Before a first Office Action on the merits, the Examiner is respectfully requested to favorably receive and enter the foregoing amendments in this case. The foregoing revisions to the specification and claims only include changes that correct certain typographical inexactitudes which existed in the application specification as originally

filed, cancels claims which were allowed in this case's parent and adds new claims for the Examiner's kind consideration. No new matter has been entered.

The Examiner is invited to note that undersigned has appended a red-line version of the amendments to the specification and a revised substitute specification (excluding the claims) as required by 37 CFR 1.121.

Undersigned has provided the Examiner with a clean copy of the claims hereinabove, as they presently stand in this case (i.e., the claims for which applicant has requested cancellation have been removed therefrom). It is to be noted, however, that undersigned has not appended a red-line version of the claims under 37 CFR 1.121, because <u>no amendments have been made</u> to claims 20-25, 34-37, 44-50, 54 and 55. They have merely been reproduced, with the cancelled claims removed, for the Examiner's ease of review.

In view of the foregoing, it is respectfully requested that the Examiner favorably receive this Preliminary Amendment, entering same into the record and proceeding with the examination of this case on the merits.

Dated: June 5, 2001

Respectfully Submitted:

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[Amendment to the Specification under 37 CFR §1.121 - Docket No. 31027-pa]

FIELD OF THE INVENTION

The instant invention relates generally to a moisture analyzer and, in particular, to a microwave moisture analyzer for loss on drying applications.

¶ This application is a division of U.S. Application Serial no. 09/086,756, filed 05/27/98, pending.

BACKGROUND OF THE INVENTION

A multiplicity of devices and analytical methods have been developed in an attempt to obtain fast and accurate quantitative analysis of a vast array of products which are manufactured subject to strict control of moisture. For example, certain products have a specific range of moisture which dictates the taste and/or texture of the product. Thus, once the consumer associates a specific taste and/or texture to the product the uniformity of that taste and/or texture becomes a hallmark to the products long term acceptance and ultimate success. Furthermore, moisture content is a specific process control in food processing, waste water treatment and materials processing.

Typically, these products require the volatilization of moisture or the like from the substance for moisture determination. In recent years, conventional microwave heating has been employed in the methods to remove various volatiles such as moisture followed by calculations of the amount of moisture lost. Conventional microwave heating requires the use of high power levels for providing effective drying due to the conventional microwave ovens employing random direction T_e waves as the dominant energy field for the drying process. As a result, these microwave ovens produce hot and cold spots, over heating edges and charring of the products being analyzed. In addition, these conventional microwave ovens failed to provide a satisfactory solution which provided fast and accurate moisture determination of the product without the degradation of the product due to these problems.

Thus, there continues to be a need for an efficient microwave moisture analyzer which offers uniformity of microwave heating and rapid moisture determining analysis without the degradation of the product due to these problems.

This is particularly important in light of the fact that most of the testing of products is related to process control in some form or another. Thus, the speed of the analysis and tests are hallmarks of high quality mass production. In addition, there is a need for a microwave moisture analyzer which provides timely feedback for maintaining tight tolerances of both the process and product produced thereby. Furthermore, a microwave moisture analyzer is needed which includes automated functions which simplify routine analysis thereby substantially eliminating the dependency of the result of the analysis on the skill and care exercised by the operator.

In addition, scales have been employed within these conventional microwave ovens to measure the weight of the product being analyzed. However, these devices have heretofore been susceptible to jarring and vibration in the working environment which resulted in anomalous weight readings. Such inconsistencies in operation result in unpredictable and unreliable moisture determination of the product.

Furthermore, none of the prior art which applicant is aware addresses the problem of continuing to dry the product after all of the moisture has been exhausted therefrom. This of course alters the mass which introduces an error in the final moisture calculation. Moreover, none of the prior art which applicant is aware addresses the possibility of a sample igniting in the chamber while doing a loss on drying process. Although the possibility of a sample igniting in the chamber while doing a loss on drying process is low, it does exist.

Therefore, not only does there continue to be a need for an efficient microwave moisture analyzer which offers uniformity of microwave heating and timely feedback for maintaining tight tolerances of the drying process, there also

SUMMARY OF THE INVENTION

The instant invention is distinguished over the known prior art in a multiplicity of ways. For one thing, the instant invention provides a microwave moisture analyzer for loss on drying applications which provides fast and accurate quantitative analysis of a vast array of products which are manufactured subject to strict control of moisture. The instant invention also provides fast and uniform drying of product samples for real-time process control without degradation of the samples due to charring. In addition, the instant invention provides microwave energy means for providing real time feedback during the drying process of the sample thus, inter alia, maintaining tight tolerances of the drying process. Furthermore, the instant invention provides a microwave moisture analyzer which is impervious to vibration and jarring in the working environment thereby eliminating anomalous weight readings which result in unpredictable and unreliable moisture determination of the sample. Moreover, the instant invention solves the problem of over drying the product and the possibility of the product igniting in the analyzer. The instant invention also includes automated functions which simplify routine analysis thereby substantially eliminating the dependency of the result of the analysis of the skill and care exercised by the operator.

In a preferred form, the microwave moisture analyzer of the instant invention includes, a power supply, a magnetron, a power module operatively coupled between said power supply and said magnetron for driving said magnetron, a wave guide communicating with the magnetron and with a microwave containment chamber for delivering energy thereto, at least one microwave energy sensor for sensing microwave energy or magnetic and/or electric field strengths within the chamber for controlling, inter alia, the loss on drying process of the

sample being assayed and determining when the drying process is complete. A precision electronic balance is operatively disposed within the microwave chamber for allowing a specimen being assayed to be weighed. In addition, a ventilation chamber is provided for venting moisture from the microwave chamber. A processing unit and associated memory allows means for data acquisition, processing and storage of data from the power module driving the magnetron, the microwave energy sensor(s) for sensing magnetic and/or electric fields and the electronic balance for weighing the initial and final weights of the specimen for loss on drying moisture analysis; b Both signaling the removal of microwave energy in the chamber.

In addition, the microwave moisture analyzer of the instant invention includes a sample rotation module which rotates the sample during the drying process. Furthermore, a smoke/gas detector module and a flash detector module can be operatively disposed within the analysis chamber 260. The smoke/gas detector module provides means indicating endpoint runover. The flash detector module provides means for providing a warning if a sample begins to ignite within the analysis chamber.

The microwave containment chamber is partitioned into a lower chamber and an upper chamber wherein the upper chamber is pivotally coupled to said lower chamber such that said upper chamber can move from a closed substantially horizontal position to an opened upright positioned for toploading of a specimen faster. The upper and lower chamber when in a closed position define a internal cavity having a base, cylindrical sidewalls extending from said base and operatively coupled thereto and a perforated top wall wherein moisture can be aspirated therethrough without allowing microwave leakage. The base of the cylindrical

loss ~~lose~~ on drying analysis. Each of the partitioned areas are independently accessible depending on requisite need. Whether it be for maintenance or subsequent utilization in its intended working environment. The area above the balance 240 and where the microwave power is outputted includes a hinged and spring lift covered microwave analysis chamber 260 (please see figure 8). The hinged cover or upper chamber 300 includes a vent means 312 (figure 11) associated therewith and circulatory means to remove moisture during a loss on drying analysis. The hinged cover 300 protects the user by a plurality of micro-switches which disable the magnetron 170 should the cover 300 be opened while the apparatus 10 is in operation or if the cover 300 is improperly closed.

In addition, and referring to figures 1, 6 and 11, the apparatus 10 includes a microwave energy module 450 operatively disposed within the analysis chamber 260. The microwave energy module 450 controls, inter alia, the loss on drying process of the sample being assayed and determines when the drying process is complete by sensing magnetic and/or electric field strength, i.e., energy within the microwave analysis chamber 260. One principal analogy of this sensing technique is that the module 450 will sense energy heretofore allocated to drying the sample wherein the sensed energy is correlative to the energy unabsorbed by the load.

Prior to the drying process sample is placed between two ~~tow~~ glass pads and disposed on a carriage 250 within the chamber 260. The carriage communicates with the electronic balance and a sample rotation module 540 via the two piece weighing rod 242. The sample is weighed prior to and after the drying process. During the drying process of the sample it is preferred that the carriage 250 is rotated by the sample rotation module 540. Thus, the two piece weighing rod 242 serves a dual purpose: providing a support member for the sample to be weighed by the electronic

display and the plurality of soft keys. The numeric keypad 90 includes ten numeric keys and a decimal and asterisk key 94, 96 allocated in four rows of three keys each thereby defining a 4 by 3 matrix. Furthermore, an oversized start key 100 is located to the right of the 4 by 3 matrix of keys 90.

The circumscribing well 58 of the upper housing 42 receives the analysis chamber 260. The upper housing 42 includes an integrally formed horizontally disposed planar work surface 62 located at the front right hand corner of the upper housing 42. The work surface 62 is formed at a lower elevation than the sloped user access area 54 and the upper chamber 300 of microwave analysis chamber 260 and can be employed as, inter alia, an area where a sample is placed between two quartz (glass) pads and/or plastic pans which are both microwave transparent. The work surface 62 transitions into a substantially planar vertically extending sidewall 64 and a front circular wall 60 of the circumscribing well 58 receiving the analysis chamber 260. In addition, the upper housing 42 includes an outer periphery with downwardly extending side walls 44, 46, 48, 50. The downwardly extending side wall 50 that defines the right side of the upper housing 42 includes an opening covered by a first air grill 66. In addition, the upper housing 42 is provided with a pair of spaced apart openings disposed in a back wall 46 for receiving a second and third air grill 67, 68 which communicate with a fan 152 cooling the electronics and power supply and the fan 176 providing temperature stability of the magnetron 170. The right side grill 66 allows air to enter through perforation disposed in side wall 34 and then into the magnetron sector, over the magnetron 170 and then out through the fan 176 disposed on the back wall 30 of the lower housing 22 and back into the environment for providing cooling of the magnetron 170.

surfaces which contact with an on/off lever 391 of at least the one micro-switch 371 for providing redundant protection from the magnetron being engaged prior to the sealing of the upper chamber with the lower chamber.

Referring to figures 10 and 11, the upper chamber 300 includes a moisture evacuation chamber 311 disposed on top of the upper cylindrical wall 302 defining the microwave containment cavity of the upper chamber. The top plate 312 of the upper chamber is perforated in a manner which allows moisture to pass therethrough without the exhausting of microwaves. The moisture is aspirated by a plurality of fans 328, 330 and 332 disposed on a back wall 326 of each of the three evacuation channels defined by a pair of out channel walls 318, 324 and a pair of inner channel walls 320, 322 as shown in figure 11. Preferably, the fans are on continuously during moisture volatilization. A dome shaped lid 334 covers the perforated top plate 312 of the upper chamber 300 and the evacuation channels wherein the fans are disposed. The fans 328, 330 and 332 can be operatively coupled to the power control module or to the central processing unit for delivering power to the fans either in a direct or controlled manner.

Referring to figure 12, a cut-away view of the microwave containment chamber in a closed position is shown thereby revealing the microwave choke channel 310 disposed in the upper sealing flange of the upper chamber and having a height of 1.338 inches. The choke geometry traps and reflects microwave energy at 1/4 wavelength to cancel the effectiveness of the energy. The choke channel 310 is a re-active choke system which presents a short-circuit impedance between the sealing flanges of the chamber 260 even if they are slightly separated or misaligned. In addition, the cut-away view reveals a first tuning rod 410 and portal wherein the tuning rod extends from the base plate across the portal opening and into the

Referring to figures 14 and 15, the carriage 250 is configured as a spoked shaped wheel having a central hub 252, a plurality of spokes 256 and an outer rim 254 wherein the central hub transitions into preferably four equally spaced apart spokes 256 terminating into the substantially circular outer rim 254. The outer rim 254 is provided with a plurality of notches 258 off set from the spokes and preferably equally spaced one from another. The hub 252 of the carriage includes a blind bore which couples to the weighing rod 242 extending through the base 262 of the lower chamber 282. In addition, and referring to figures 14, 16a and 16b, the tuning rods 410, 420 are shown to be disposed in the base plate of the lower chamber at a distance distal from the interior cylindrical wall thereof. The tuning rods each include a first end and a second end. The first ends 412, 422 of the tuning rods are disposed in the base 262 of the lower chamber 282 and then transitions into medial portions 414, 424 which are angled toward the interior side wall of the lower chamber wherein the tuning rods terminate into substantially horizontal ends 416, 426 which are received in apertures disposed in the cylindrical side wall of the lower chamber. Note that each tuning rod has a height H in which it vertically extends from the base before transitioning into its medial portion which angles toward the cylindrical lower interior wall of the lower chamber. The tuning rods are toleranced around a nominal diameter. In addition, the tuning rods are spaced a distance L away from the cylindrical interior wall such that the rods 410, 420 straddle the portals 264, 266 respectively.

The tuning rods preferably bisect the portals at a median location wherein the portals are divided into equally spaced sectors. The tuning rods 410, 420 have a diameter of 0.094 inches. As shown, the tuning rods include medial portions 414, 424 with first ends 412, 422 and second ends 416, 426. Each first end ha~~ving~~s a length

[Amendment to the Specification under 37 CFR § 1.121 [Docket No. 31027-pa]

rod in the near field of the inlet-coupling hole or portal than arbitrarily in the cavity. The preferred placement is just in front of the coupling hole on the cavity side of the coupling hole.

Referring to figures 13 through 17 the tuning rods 410, 420 are between the cylindrical side wall above the coupling slots or portals and the flat circular wall or base some distance inwards radially. The general geometry is shown in figure 14, 16a and 16b. There are two perpendicular slots or portals fed in (almost) quadrature. The system in figure 23 is doubled.

It has been found that the tuning rods provide a positive action, resulting in a stabilization of the impedance matching of the apparatus 10 (this is crucial, since the load~~s~~ is small).

THE CAVITY FEED AND POSSIBLE MODES

The apparatus is supposed to have two resonances: TM_{111} and TM_{012}.

RESONANT ACTION OF THE DEVICE STRUCTURE

One may envision the tuning rod situation by supposing that two oppositely propagating waves from one narrow wall to the other interface in such a way that maximum field strength is obtained with minimum energy input - which is a very suitable way of defining resonance here.

What does the resonance result in? - The simplest answer is that a maximum part of the available power flow is "converted" to the resonant filed pattern; when this happens there will be less impinging power left so that the resonance will be self-limiting in amplitude. Generally, there will be an almost full nulling of one impinging filed component by the resonant field. This situation is shown in figure 23.

In effect, the incoming H field from each slot or portal will create a resonance (if the device dimensions are right) which will weaken the total H field at the wall in the region. Instead, there will be a strong H field around (and particularly outside) the "inner leg" 412, 422 of the device, where there is no strong field without the device.

It is readily seen that the inner leg will act as a quite powerful excitor of a circulating H field, which will go over into a vertical E field upwards. This combination of E and H fields may couple quite well to a H field loop (with accompanying vertical E field) of the TMz_{11} mode. There will thus be a good field matching from the device region (medial portion 414, 424) to the desired cavity mode.

THE COUPLING BETWEEN THE CAVITY AND DEVICE REGION RESONANCES

This coupling function can be explained as follows: the coupling factor (in principle: transmission impedance equality) between the resonant device region and the cavity resonance will become quite frequency-sensitive, due to the reasonably high Q value of the device region. If the device region is now chosen to be resonant at a frequency some ten(s) of MHz away from 2460 MHz, the cavity resonance with a changing (i.e. drying) load will move along the resonant curve of the device region.

- If the Q value of the cavity is high, its own resonance will dominate and the coupling is good. When the cavity Q value goes down, the coupling will typically be less (since high coupling for a small sample is desirable). However, since the overall resonant frequency will change less due to the resonance coupling between the two resonances. Furthermore, the coupling can be made to increase (due to the slope of the device region being active at the "start" of the process), and the impedance matching can be made fairly constant during the whole process.

There are thus several parameters which together determine if the combination of cavity and device region will work well:

- The resonant frequency of the cavity resonance without device (and at strong undercoupling), as a function of the load variations.
- The Q value of the cavity resonance, and its variation with the specified load variations.
- The field matching of a primary (slot) feed to the resonant mode(s) (this contributes to the determination of also the coupling factor).
- The field matching of the device region to the cavity mode (this contributes to the determination of also the coupling factor).
- The resonant frequency of the device region (under conditions of removed cavity).
- The internal Q value of the device region.
- The coupling factor from the slot to the cavity resonance, as a function of the load variations.
- The coupling factor from the slot to the device region (i.e. how much of the overall coupling is determined by the device region).

The unique configuration and dimensions of the wave guide will be delineated with the help of figures 17 and 18. The wave guide is substantially Y shaped having a base wave guide 202 which is approximately 3.5 inches in length and 2.13 inches in width, the first wave guide feed 204 having a length of 3.23 inches and a width of 1.6 inches, and the second wave guide feed 206 having a length of 4.8 inches and a width of 1.6 inches. The first and second wave guide feeds 204, 206 bifurcate from the main wave guide at a intermediate junction 208. A splitter can be added at the junction to assist in setting up the phase shift. The first wave guide

feed 204 transitions into the first portal 264 disposed in the base 262 of the lower chamber 280 while the second wave guide feed 206 transitions into the second portal 266 disposed in the base plate 262 of the lower chamber 280. The mid-point of the first portal is at a 31.35 degree angle with respect to a plane P bisecting the transitional area of the first wave guide feed and the second wave guide feed. The mid-point of the second portal has an angle of 62.05 degrees with respect to this bisecting plane as is shown in figure 17.

Referring to figure 18, the portals 264, 266 of the base 262 ~~to~~ provide openings for delivery of microwave energy to the sample being assayed and subsequently manipulated for a loss on drying analysis. The portals 264, 266 are substantially canoe shaped openings having radiused bottoms of preferably 3.130 inches away from a mid-point of the centralized bore disposed in the base of the lower chamber. The radiused bottom transitions into radiused corners having a 0.1 inch radius and a ~~cord~~ chord extending from one radiused edge to the other thereby forming a closed canoe shaped opening.

Referring to figure 19, the magnetron is operatively coupled to an outside wall of the base branch of the quadrature wave guide and communicates with the base branch of the quadrature wave guide via a magnetron antenna hole 220 disposed through a side wall of the base branch of the wave guide. In addition, a tuning stub 222 extends through an outside wall and into the first branch 204 of the wave guide 200 at a location proximate the bifurcation of the wave guide into the first and second branches. The tuning stub 222 is dimensioned to attenuate a third energy mode such that there are only two substantial energy modes being delivered to the chamber. In other words, tuning stub 222 filters out measurably a third mode,

assuring only two modes enter chamber at peak efficiency. The third mode used to have a drastic effect ~~affect of~~ sample position tolerance and uniform drying.

A preferred embodiment of the rotation means 450 is shown as 570 in figures 20a through 20d. Referring to figure 20a, rotation means 570 includes an engage/disengage servomotor 572 which is coupled to the bottom of the chamber via a bracket 576. The bracket 576 includes an interior hollow area 578 which allows a shaft 574 of the servomotor 572 to couple to a drive motor 582 via a rotatable platform 580. The drive motor 582 includes a shaft 584 coupled to a drive motor wheel 586. The drive motor wheel 586 coacts with a friction drive wheel 588 which is coupled to the upper member 542 of weighing rod 242 for rotating the carriage 250 and thus the sample. The drive motor 582 preferably has bi-directional capability for clockwise or counterclockwise rotation of the carriage 250 and variable speed control (angular velocity) for variable clockwise or counterclockwise rotative speed of the carriage 250.

The upper member 542 is coupled to the lower member 544 via sleeve 590 wherein the upper member is allowed to turn within the sleeve when the friction drive wheel 588 is rotated.

Referring to figure 20a, when the rotation means is actuated the engage/disengage servomotor 572 rotates the drive motor 582 in a clockwise or in a counterclockwise direction along double ended arrow "X". In an engage mode the power control board signals the servomotor 572 to rotate the platform 580 in a counterclockwise direction such that the drive motor wheel 586 contacts the friction drive wheel 588. Simultaneously, the drive motor is activated by the power control board to rotate the drive motor wheel 586 in a clockwise or counterclockwise direction along double ended arrow "Y". Thus, when the motor wheel 586 contacts

A change to a larger sample size should be considered if the sample is heterogeneous and great representation is necessary to achieve better reproducibility. A change to a smaller sample size should be considered to reduce the analysis time.

A change to a lower power level should be considered if the sample after testing appears scrorched or a higher recovery than expected occurs. A change to a higher power level should be considered to reduce the analysis time. In some cases it may be advantageous to develop a two step drying procedure where the power level can be reduced to a lower level after the set corresponding period of Time 1.

Moreover, having thus described the invention, it should be apparent that numerous structural modifications and adaptations may be resorted to without departing from the scope and fair meaning of the instant invention as set forth hereinabove and as described hereinbelow by the claims. For example, an embodiment is contemplated once having had the benefit of the foregoing teachings, wherein a method for loss on drying includes the steps of placing a sample in a microwave, powering the microwave to dry the sample, monitoring and/ or sensing the microwave energy within the microwave and weighing the sample either continuously or intermittently (e.g. at sensed endpoints) while powering the microwave. Alternatively, an embodiment is envisioned wherein a method for loss on drying may include the steps of placing a sample in a microwave and powering the microwave to dry the sample for an initial period of time and then intermittently or continuously weighing the sample while monitoring and/ or sensing the microwave energy after the initial time to an endpoint condition. Therefore, the spirit and scope of the appended claims should not be limited to the description as set forth hereinabove.

ABSTRACT

A toploading weighing instrumentality which determines loss on drying by a cylindrical microwave. The cylindrical cavity of the microwave includes a power supply, a magnatron, a power module operatively coupled between said power supply and said magneton for driving said magneton, a wave guide communicating with the magneton and with a microwave containment chamber for delivering energy thereto, at least one microwave energy sensor for sensing microwave energy or magnetic and/or electric field strengths within the chamber for controlling, inter alia, the loss on drying process of the sample being assayed and determining when the drying process is complete. A precision electronic balance is operatively disposed within the microwave chamber for allowing a specimen being assayed to be weighed. In addition, a ventilation chamber is provided for venting moisture from the microwave chamber. A processing unit and associated memory allows means for data acquisition, processing and storage

Continuation of red-line changes to "In the Abstract".

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of data from the power module driving the magnetron, the microwave energy sensor(s) for sensing magnetic and/or electric fields and the electronic balance for weighing the initial and final weights of the specimen for loss on drying moisture analysis. Both signaling the removal of ~~moisture~~ microwave energy in the chamber.

[Pg. 74 - chgs - continued]